Engineering Models of High Explosives

Annual Explosives Research Review

Jobie M. Gerken
Joel G. Bennett
Engineering Analysis

Objective

- Engineering Simulations of STS and Abnormal Loading Scenarios
  - Mechanical Response (STS/Abnormal)
    - Load Rates - ~0 /s to > 3000 /s
    - Material State Changes
  - Thermal(Abnormal)
    - Chemical and Mechanical Effects
    - Affect Mechanical Behavior and Reaction Violence
  - Failure(Abnormal)
    - Loss of Mechanical Strength
    - Cracking/Surface Creation
      - Affect Mechanical and Thermal Behavior

ViscoSCRAM

- A Robust Engineering Constitutive Model for PBX 9501
  - Mechanical
  - Bulk Thermal
  - Ignition
- Collaborative Effort
  - T-1, T-3, T-14, DX-2, MST-8, ESA-EA
  - Repa / Hurley / Howe Support

ViscoSCRAM Validation

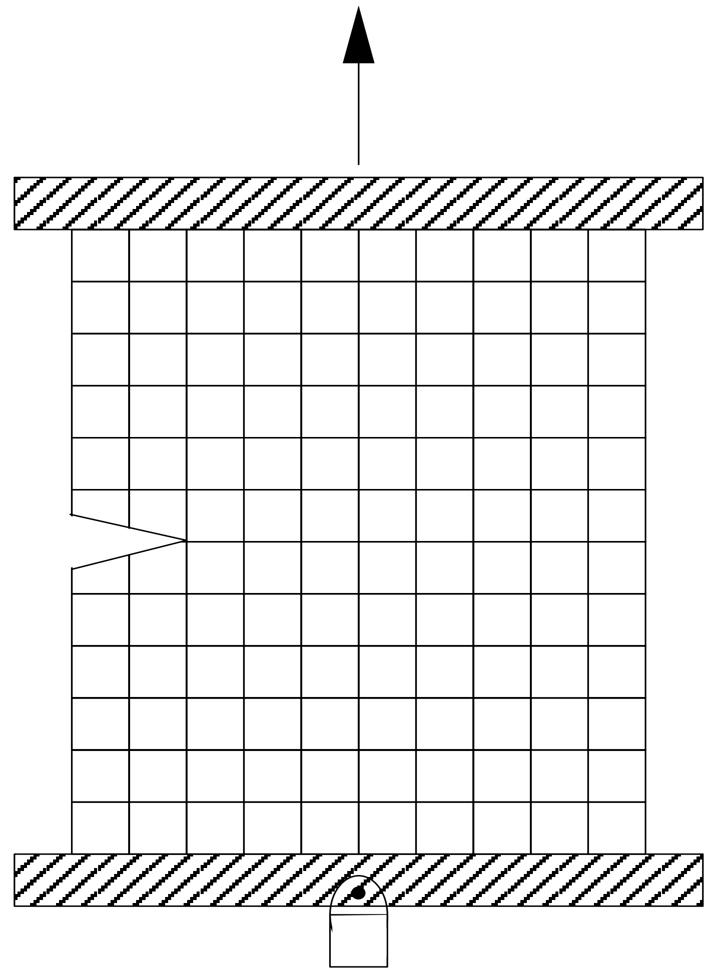
- Mechanical Response Validated by comparison with Experimental Data
  - Low Rate - Idar
  - High Rate - Gray
  - Three Point Bend - Collin/Sadler
  - Asay Impact - Asay

ViscoSCRAM Validation

- Thermal - In Progress
  - Stevens Impact
    - Large
    - Small

Crack Modeling

- 2-Dimensional Fracture Model
  - Distribution of Pre-existing Mini Cracks
  - Separation Along Element Interfaces
  - Smith, Bennett, Gerken
  - Support:
    - Asay, Howe, Dey

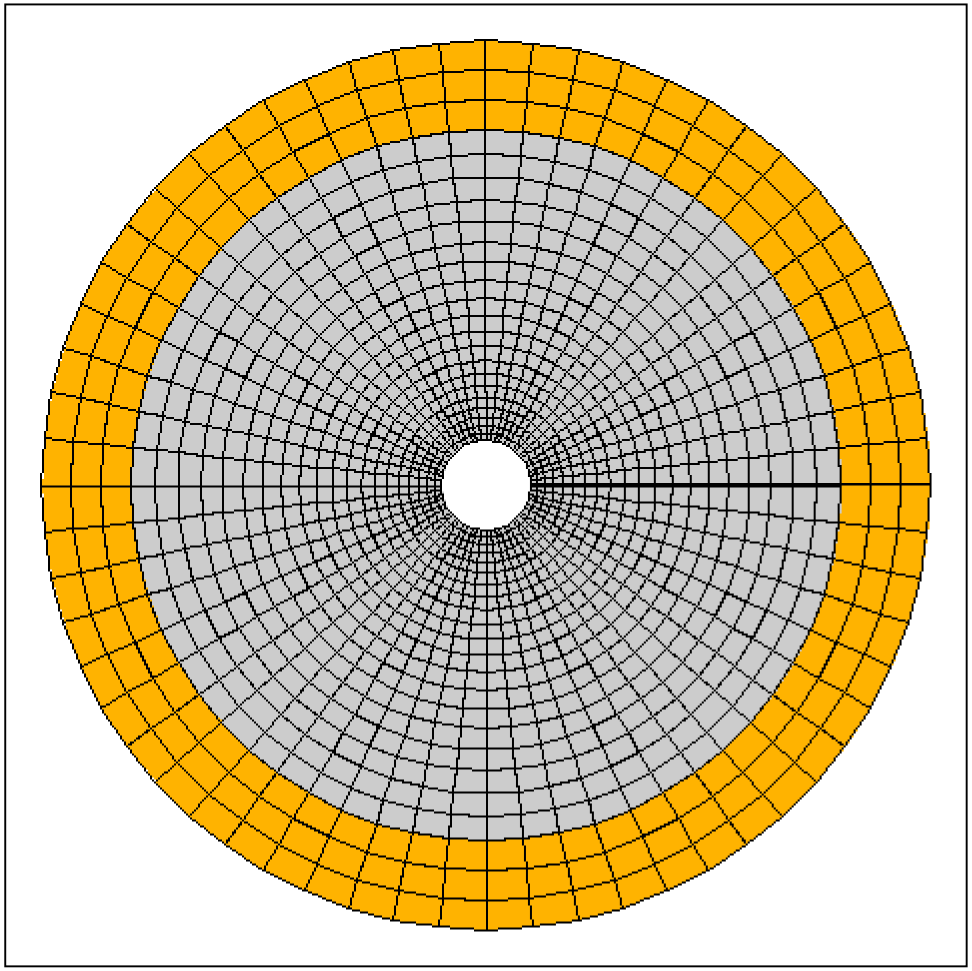


Crack Modeling Validation

- Qualitatively Validated by Comparison with Known Fracture Solutions and Experiments
  - Compact Tension
  - Single Edge Notched Beam
  - Cracked Cantilever Impact - Stout/Liu
  - Mechanically Coupled Cook Off - Asay *et al*.
- Quantitative Validation is In Progress
  - Fracture Criteria Don’t Match Known Solutions
  - Dynamic Fracture Validation is Elusive

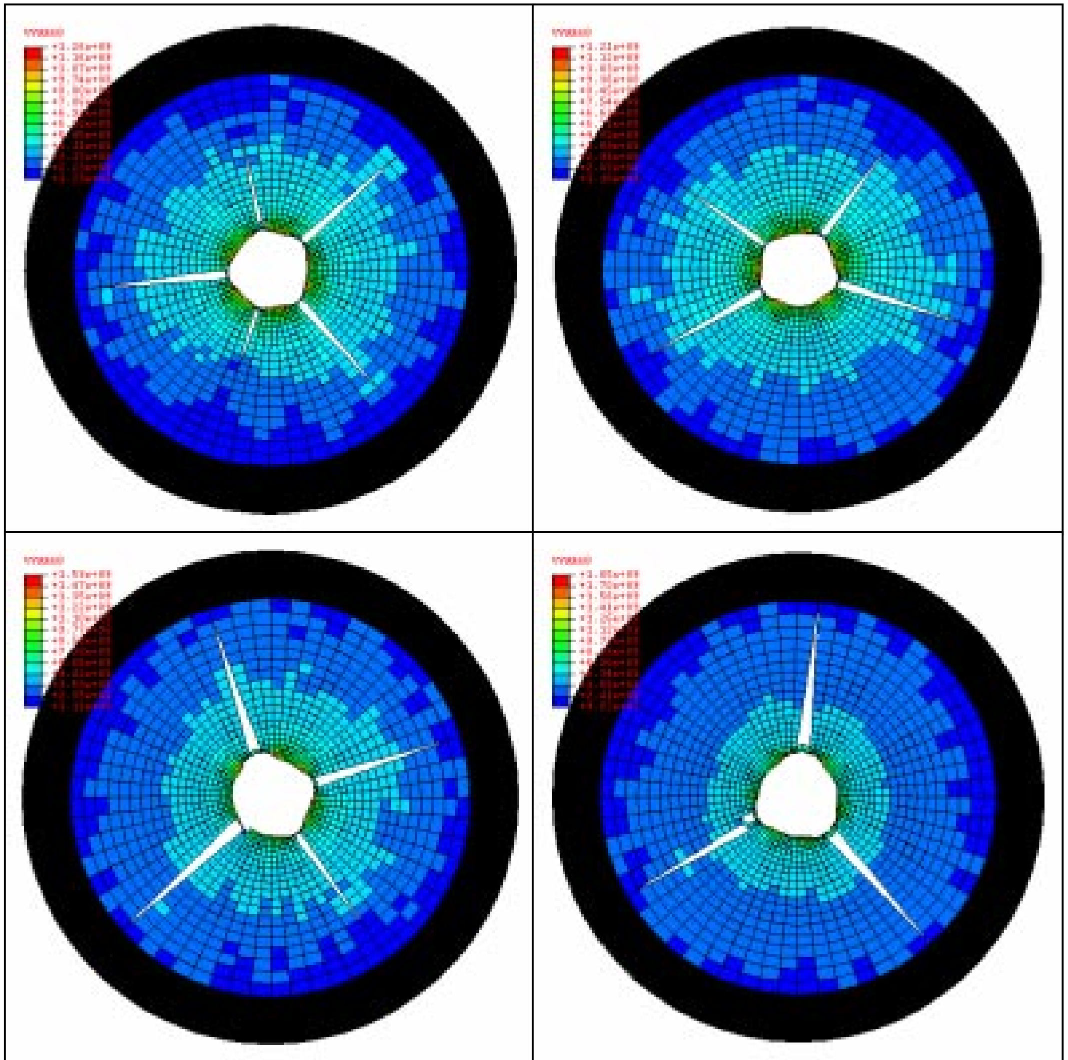
Modeling the MCCO

- Model
  - ABAQUS - Implicit
  - 2D -Plane Strain
  - Thermal Expansion
  - Elastic/Plastic Cu
  - ViscoSCRAM HE
  - Discrete Fracture in HE
  - Random Interface Crack Sizes for Discrete Fracture
- Method
  - Heatup 120 K
  - Pressurize inner Surface 5 MPa/μsec
  - Pressurize Discrete Crack Faces as They Form



Modeling the MCCO

- Different Random Distribution Results in Different Crack Pattern
- Always 3 to 5 Large Discrete Cracks

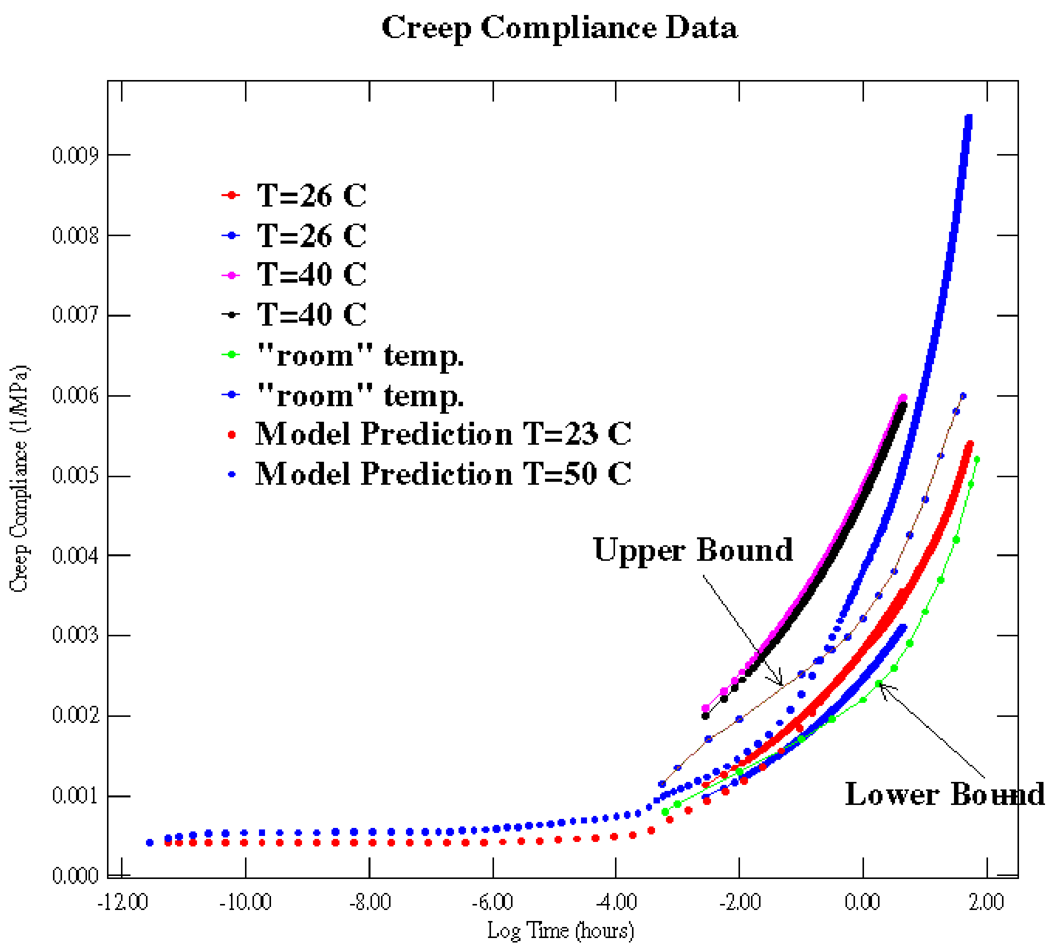


ViscoSCRAM Progress

- ViscoSCRAM has been Implemented in our Widely Used Engineering Codes
  - ASCI
    - PRONTO3D
    - PARADYN, DYNA3D
  - IMPLICIT
    - NIKE(In Progess)
    - ABAQUS/STANDARD

ViscoSCRAM Progress

- Creep Modeling

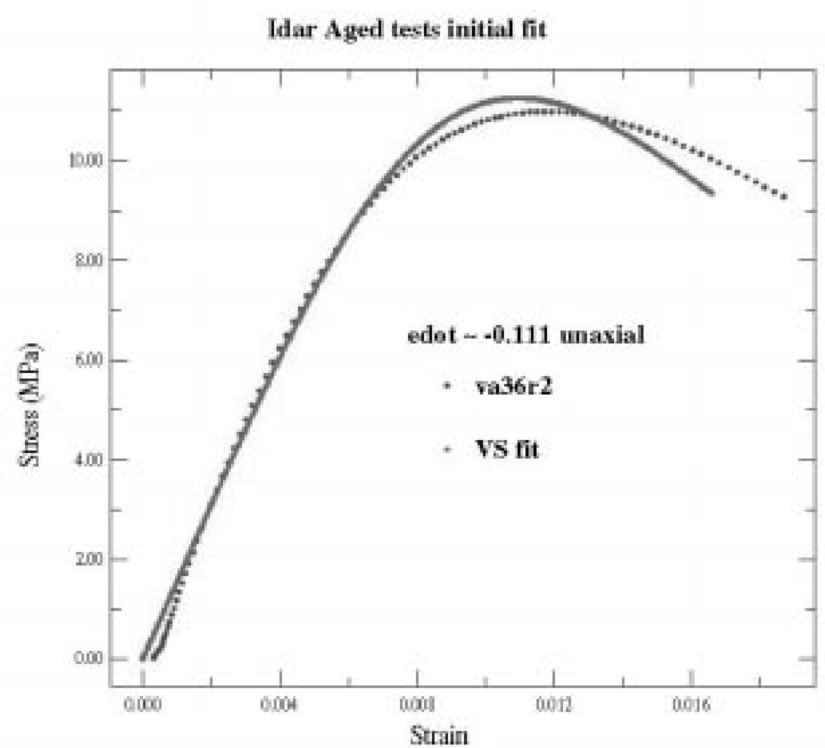


ViscoSCRAM Progress

- Equation of State Improvements (In Progress)
  - Old Method used Elastic Equation of State
    - Probably O.K. for Solid Material
  - New Method - Tarver Kinetics & P-V Relation
    - Takes into Account the Changes as HMX Decomposes into Gas

ViscoSCRAM Progress

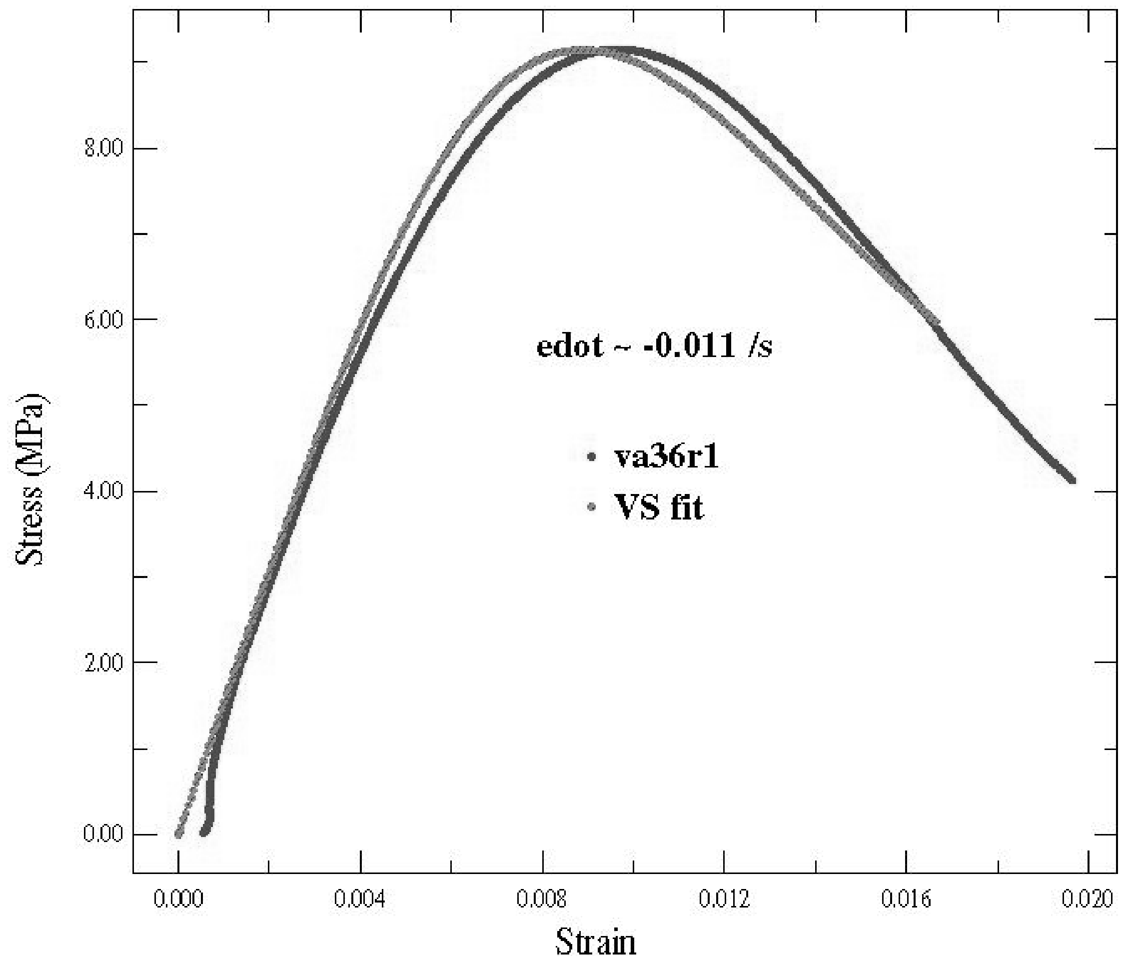
- **ViscoSCRAM Fits of the Stress-Strain Date from the Accelerated Aging Tests are Complete for the Virtually Aged PBX 9501 Formulated from 36 Day Artificially Aged Estane**
- **For the Two Rates Available, the Damage Growth Law that Defines the Peak Stress, Peak Strain as a Function of Rate Has been Estimated and is Being Used in the First Assessment of Mechanical Response Changes**



ViscoSCRAM Fit for VA36R2 Test Data

ViscoSCRAM Progress

- Fits for all available rates have been completed



Cracking Progress

- Expanded Abilities by 1 Dimension (i.e 3D)
  - Incorporating a 3D fracture method into the code DYNA3D
    - No Implicit Effort
  - Very Similar in Spirit to 2D method
    - Distribution of Pre-existing Mini Cracks
    - Separation Along Element Interfaces

Cracking Progress

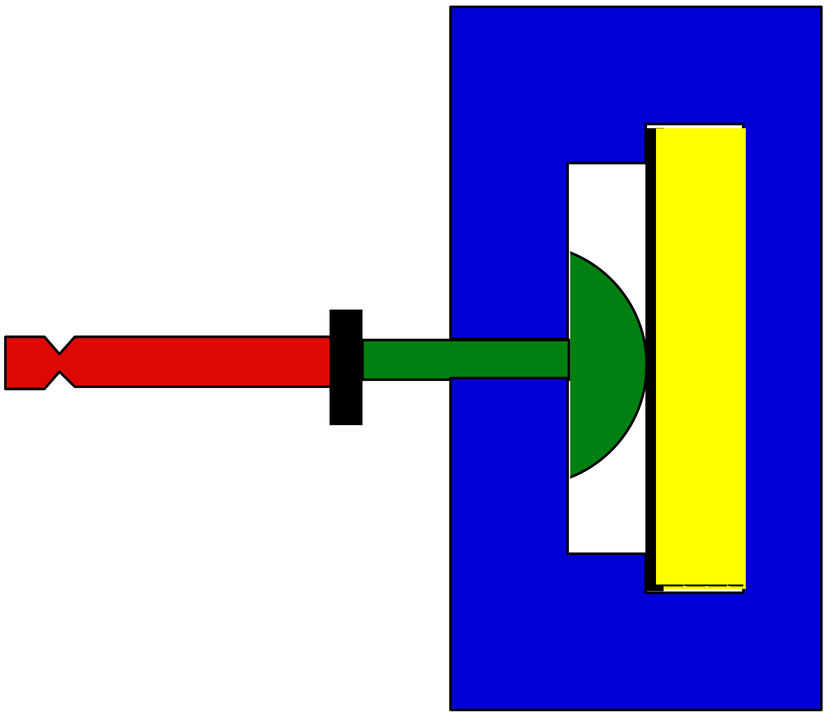
- 3D Methodology
  - Construct a Mesh of Elements with Unique Nodal Connectivity
    - Imagine they are an assembly of building blocks
  - Embed Virtual Crack
    - Lognormal Distribution (or other)
  - Find Coincident Nodes
    - average nodal forces
  - Evaluate Fracture Criterion (Criteria)
    - stresses, equivalent elasticity parameters
    - handle interface failure - detach nodes
  - Evolving Contact to allow for “Rubblization”
    - auto-contact treats all external faces as contact surfaces
    - remove interior faces from contact until fracture

In Progress

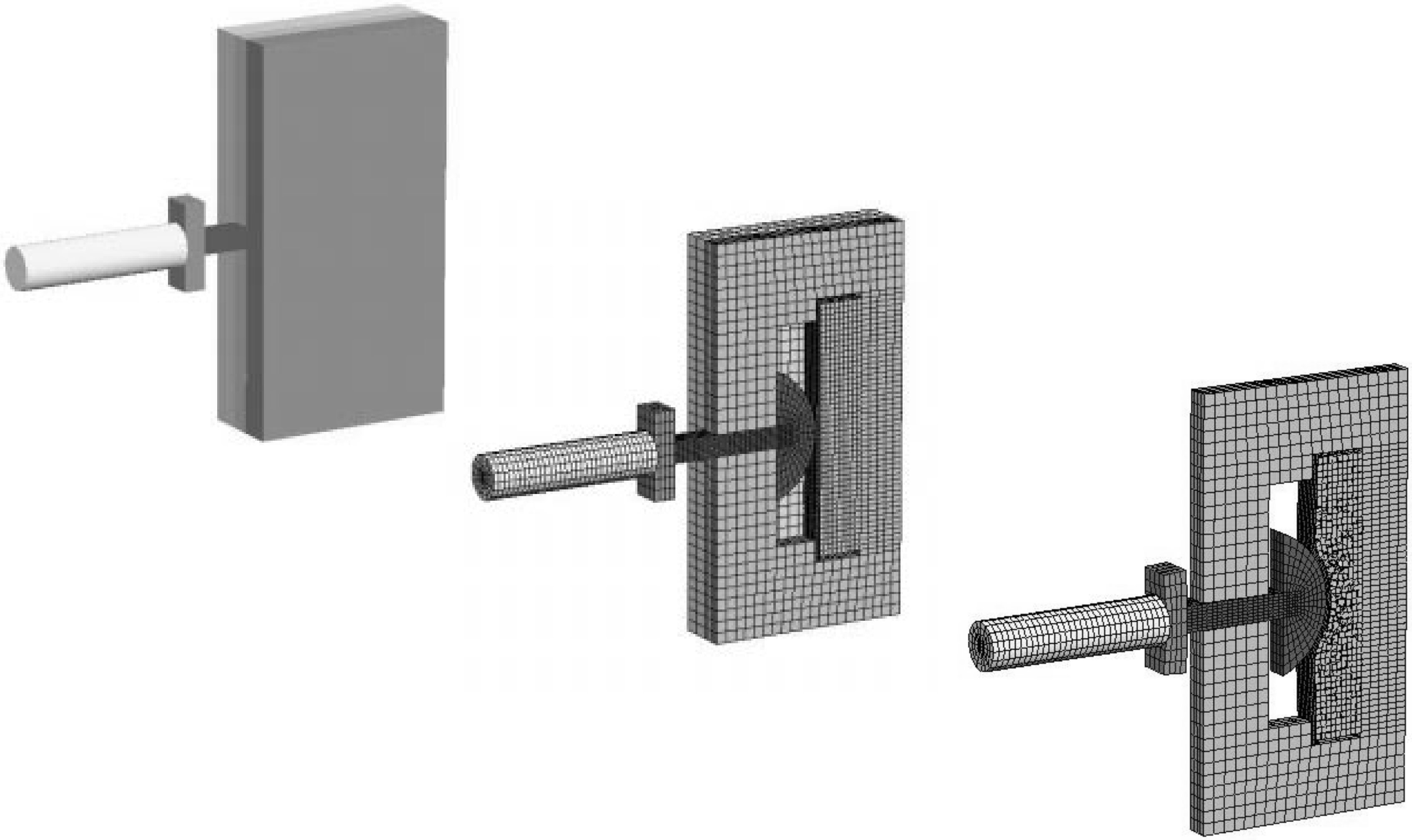
- Make process transparent to user
  - current - interface nodes, adj. Element # in deck
  - Future - internally generate info from standard mesh
    - need to add nodes and redefine element connectivity
    - problem - DYNA3D needs number of nodes for memory allocation
- Improvements to Fracture Criteria

3D Fracture Simulations

- Small Scale HEVR



3D Fracture Simulations



3D Fracture Simulations